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Segmented patching broadcasting protocol for video data

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ABSTRACT

In adaptive segment-based patching scheme, the video is divided into fixed number of segments, which are transmitted over the server channels. For efficient transmission of the video segments, the server channels are classified into two types – regular and patching channels. A regular channel generally transmits fixed number of segments and a patching channel helps transmitting those segments that cannot be provided by any regular channel to the users. The number of segments transmitted by the first regular channel is decided by the number of regular channels that are allocated to the video by the video server. Other regular channels transmit pre-specified number of segments. This scheme estimates the bandwidth of the patching channels based on the requests received at the video server in terms of fixed time intervals, called time slots. The bandwidth estimation in this scheme is less accurate because for multiple requests received in a time slot more than one patching channels are used. Second, the probability distribution considered in this scheme does not satisfy the basic rule, i.e., the sum of all probabilities is not 1. In this paper, we address these issues and propose a new protocol named as Segmented Patching Broadcasting Protocol for Video Data. The average server bandwidth allocated to the patching channels is much less as compared to the adaptive segment-based patching scheme because only one patching channel is sufficient for any number of requests received in a time slot.

1. Introduction

In multimedia applications especially video related ones, the objects require large amount of storage and for their transmission large bandwidth is needed. The development of computing and communication technologies are making these applications feasible. The video-on-demand (VOD) services are one such application. The digital technologies have increased the data rate by many fold, which is still a scarce resource as the bandwidth demand is increasing for new video applications. So, the bandwidth should be used efficiently. For efficient usage of the bandwidth, it is important to know the popularity of videos. There have been various studies related to the videos' popularity. In [1,2], the video popularity has been reported to follow the Zipf distribution with the skew factor 0.271, i.e., 80% of the users' demand is for about 20% of the most popular videos and 20% demand for 80% videos. This fact helps in designing the video server by maintaining popular videos in the main memory and less popular videos on the secondary or tertiary memory. For popular videos, efficient utilization of the bandwidth may be done using the broadcasting techniques. A broadcasting scheme implicitly assumes very high request arrival rate and does not take it explicitly into consideration. In broadcasting, same type of contents is transmitted after a regular interval. Generally, all users are not interested in viewing the same type of contents and broadcasting is not a good solution. In such cases, multicasting based techniques are more useful. For example, the senior citizens may not like to view those contents that interest children. To handle such situations, the users are grouped into different classes and for each class same type of contents is provided. This type of data transmission is called multicasting. Multicasting helps in providing different types of services each for a class of users, but for low user requests the bandwidth is under-utilized. The bandwidth is a scarce resource and one cannot bear its wastage. In such cases, the patching based schemes are more beneficial. In these types of schemes, two types of channels – full-length and patching channels – provide the video data to user requests. A full-length channel, also called a regular channel, transmits the data after a regular time interval and the missing video data is provided by the patching channels of appropriate lengths. In patching based schemes, a user downloads and stores the future playback data into the system buffer from the on-going full-length channels. The remaining data are provided by allowing a fresh transmission using a patching channel. Some important patching based schemes have been discussed in [3–7]. There are other classes of schemes, which are based on batching. In batching based schemes, the requests are collected in batches and then a regular channel is used

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to provide them the video data. In [8], adaptive segment-based patching scheme has been discussed. This scheme reduces the bandwidth requirement as compared to the standard patching based scheme by combining the benefits of batching and patching techniques. This scheme, however, has some drawbacks: (i) The bandwidth of the patching channels has been derived using the multiple patching channels for multiple requests received in a time slot. This fact is less accurate because any number of requests received in a time slot can be serviced by just one patching channel. (ii) The probability distribution does not follow the basic rule, i.e., sum of all probabilities is not 1 (refer Eqs. (1) and (4)). In this paper, we address these issues and propose a new scheme, called Segmented Patching Broadcasting Protocol for Video Data.

The remaining paper is organized as follows. Section 2 reviews the adaptive segment-based patching scheme as the proposed scheme addresses its drawbacks and provides their solutions. Henceforth, the adaptive segment-based patching scheme will be referred to as adaptive scheme in this paper. In Section 3, the proposed scheme, i.e., segmented patching protocol for video data is discussed. Section 4 presents the results. Finally, in Section 5, we conclude the paper.

2. Adaptive segment-based patching scheme

In the adaptive segment-based patching scheme, the batching and patching techniques have been integrated. This scheme performs better than the standard patching-based scheme because it dynamically estimates the number of (regular) channels based on the request arrival rate in such a way that the bandwidth requirement is minimized. In this scheme, the video is divided into equal-sized segments depending on the maximum number of regular channels allocated to the video by the video server. If K denotes the maximum number of regular channels, then the number of video segments, denoted by N, that can be transmitted over K channels is given by

$$N = 2^K - 1.$$

The size of a segment, denoted by S, is given by

$$S = D/N = D/(2^K - 1),$$

where D is the video length in time units.

The segment size determines the user's waiting time. If the regular channels are less than the maximum number, then one of the regular channels needs to transmit more segments than its normal allocation; otherwise all users may not get video data in time. A scheme has its own architecture that decides the allocation of video segments to each of the (regular) channels allocated to the video by the video server. If the arrangement of the segments' allocation is changed, then the scheme may not provide the video data to all users in time. Here, *normal allocation* means that the segments allocated to a (regular) channel are as per the scheme's architecture. Normally, in almost all the schemes the first regular channel transmits only the first segment so that all users can get the video data in time. In [8], the first regular channel transmits more than one segment. Other regular channels transmit the pre-specified number of segments which depend on the number of segments transmitted by the first regular channel. The number of segments transmitted by the first regular channel is determined by the number of regular channels available for the video. Since the first regular channel transmits more segments than its normal allocation, it means that all users cannot get the required data in time. To provide the uninterrupted data on time to all users, especially, the segments transmitted by the first regular channel, we need to support some patching channels. Depending on the time slot in which the request arrives, a patching channel of appropriate length is initiated to provide the missing initial data to users. If out of K regular channels, R $(1 \leqslant R < K)$ is the available regular channels denoted by $C_0, C_1, \ldots, C_{R-1}$ at a given point of time, the first regular channel C_0 transmits the first $(2^{K-R+1} - 1)$ segments, periodically and repeatedly. The second regular channel C_1 transmits next 2^{K-R+1} segments and the ith regular channel C_{i-1} transmits 2^{K-R+i} segments starting with index 2^{K-R+i} to $(2^{K-R+i+1} - 1)$. Since the first regular channel C_0 transmits $(2^{K-R+1} - 1)$ segments, denoted by N_0, periodically and repeatedly, the delivery period of this channel is $(2^{K-R+1} - 1)S$, where S is the segment size (in time units). The maximum length of any patching channel is determined by the number of segments transmitted by the first regular channel and the segment size. This, denoted by L_{max}, is given by

$$L_{max} = (2^{K-R+1} - 2)S = (N_0 - 1)S. \quad (1)$$

The average length of a patching channel in [8] has been taken as $(2^{K-R} - 1)S$ (refer (3) in [8]), which is the average of the minimum and maximum lengths of the patching channels, i.e., $((2^{K-R+1} - 2)S + 0)/2 = (2^{K-R} - 1)S$. The bandwidth required by the patching channels has been estimated as follows. Let the user requests are received at the video server as per the Poisson process with parameter λ. The probability of receiving r user requests in time duration of length S is given by

$$P_r = P(Req = r) = \frac{(\lambda S)^r e^{-\lambda S}}{r!} \quad \text{for } r = 0, 1, 2, 3 \ldots \quad (2)$$

Here, Req is a (random) variable signifying the number of user requests received in the time length S.

The bandwidth required for the patching channels, denoted by B_{patch} (refer (4) in [8]), is given by

$$B_{patch} = L_{\max} * \frac{\lambda S}{S} * P_p = L_{\max} * \lambda * P_p, \quad (3)$$

where $P_p = (1 - P_0)$.

In (3), P_p does not really satisfy the basic rule of probability distribution, i.e., sum of all probabilities is not 1. For $p = \infty$, it satisfies this condition as shown below:

$$\sum_{p=1}^{\infty} P_p = 1 - e^{-\lambda S}.$$

But, $p = \infty$ implies that the number of segments transmitted by the first regular channel as infinite, which is less accurate. Substituting the value of P_p in this equation, we have

$$\sum_{p=1}^{\infty} \frac{(\lambda S)^p e^{-\lambda S}}{p} = 1 - e^{-\lambda S}.$$

It satisfies the basic rule of probability for p infinite, but the first regular channel transmits only the finite number of segments. Since each segment occupies a time slot, the number of time slots occupied by the segments on the first regular channel is finite. It means that a patching channel is of finite length. In following section, we address these issues and propose a new scheme.

3. Segmented patching protocol for video data

In the proposed scheme like the adaptive segment based patching scheme, the video is divided into equal-sized segments based on the bandwidth allocated to the video by the video server. The maximum number of regular channels that can be allocated to the video determines the number of segments and their size. The number of segments transmitted by the first regular channel decides the maximum length of a patching channel and their bandwidth. The number of segments transmitted by the first regular channel is decided by the available regular channels. A regular channel other than the first one transmits the pre-specified